Building Broader Knowledge: Supporting Children's Active, Outdoor Science Exploration in Urban Environments

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Executive Summary

Children's early understanding of science is a key factor in their school readiness and future science learning, and over the past 20 years there has been a growing emphasis on improving their understanding of environmental science in particular. Unfortunately, most children are not getting the kinds of experiences needed to deepen their understanding of foundational scientific ideas, nor are they engaging meaningfully with the practices of science. This problem is even more profound in urban settings and for children from low-income and diverse communities.

Informal educational programs in urban settings can provide the ideal contexts for science learning and are well-positioned to fill in experience gaps that put many students at a disadvantage in school and beyond. To leverage this potential, media producers at WGBH and researchers at EDC partnered to launch *PLUM Rx: Researching a new pathway for bringing active science exploration to urban families* (NSF Grant #1516466). The 3-year initiative builds on PLUM LANDING, an NSF-funded, PBS KIDS project that uses animations, games, and hands-on activities to motivate children to investigate the natural world. With *PLUM Rx*, WGBH and EDC have (1) developed a better understanding of the needs and opportunities for active, outdoor environmental science exploration among informal programs that serve urban children ages 6-9 and their families; (2) developed a toolkit of resources that expands PLUM LANDING's rich array of media assets in order to support informal educators and urban families when engaging in environmental science activities, and; (3) built knowledge and informed the field about the circumstances, educator practices, and resources that support the effective integration of science activities and digital media to spark and sustain urban families' exploration of core environmental science concepts in natural environments.

This report looks across multiple phases of work to discuss the *PLUM Rx* project's contribution to broader knowledge about supporting children's active, outdoor science exploration in informal, urban settings. The *PLUM LANDING Explore Outdoors Toolkit* that resulted from this work is designed for use by outdoor prescription programs and a broad range of informal education programs serving urban children and families. This report describes (1) the rationale for the design principles that guided *Toolkit* development, (2) the *Toolkit* components developed in accordance with the design principles; and (3) key findings about the ways in which the integration of the design principles served to support urban children's engagement in informal, active, outdoor environmental science learning.

The design principles reflect our efforts to support informal education organizations, educators, and parents in promoting outdoor science engagement and learning among urban youth and families by leveraging their assets while also addressing constraints that often make engagement in outdoor science activities difficult. The design principles fall into six categories: 1) increasing access to science learning opportunities, 2) preparing educators and parents for science activities and supporting implementation, 3) optimizing time and space available for outdoor informal science activities, 4) fostering the achievement of multiple organizational and familial priorities, 5) ensuring safety, and 6) using technology and media in meaningful and developmentally appropriate ways.

Guided by these design principles, our iterative development and testing of the *Toolkit* enabled the creation of a much-needed, publicly available set of resources for use by families and informal organizations nationwide. Additionally, the *Toolkit* can serve as a model for others seeking to bring active, outdoor science learning opportunities into the lives of urban children and their families.

Background and Purpose

Children's early understanding of science is a key factor in their school readiness and successful future science learning (Duschl, Schweingruber, & Shouse, 2007; National Science Teachers Association [NSTA], 2014). However, to become robust scientific thinkers, children need rich and ongoing opportunities to engage in science learning across a variety of contexts. For this reason, policymakers and practitioners agree that our country must pay more attention to science teaching and learning in childhood (Duschl et al., 2007; Eshach & Fried, 2005; National Association for the Education of Young Children [NAEYC], 2009; National Science Board, 2009).

Over the past 20 years, there has been a growing emphasis on improving children's understanding of environmental science in particular. In 2003, the National Council for Science and the Environment called for curriculum resources that help children develop an understanding of environmental science (NCSE, 2003). In 2005, the United Nations announced a "Decade of Education for Sustainable Development," a ten-year effort to improve environmental education across the globe. In 2010, the Obama Administration announced the Blueprint for Reform, a vision for children's education that, for the first time, included environmental science education (U.S. Department of Education, 2010). More recently, the Next Generation Science Standards (NGSS Lead States, 2013) reflects the call to expose children early to environmental science, raising the bar for science education and achievement across all grades.

Unfortunately, children often are not getting the kinds of experiences needed to deepen their understanding of a broad range of scientific ideas, and often are not engaging with the practice of science (Education Development Center [EDC], 2013). This problem is even more profound for children from urban, low-income, and diverse communities, where children have fewer opportunities to engage with science in school (Blank, 2012; Buxton & Provenzo, 2007). They also have fewer opportunities to explore science outdoors, in part because educators in urban settings feel that nearby outdoor locations, such as city parks, are not appropriate places to learn environmental science and do not represent nature (Simmons, 1998; Bruyere, Wesson, & Teel, 2012).

Informal education programs (IE programs) offer a pathway to provide children with meaningful learning experiences to supplement those provided in school. Although the majority of education reform efforts have focused on schools, children of school age spend only 20 percent of waking hours in school. The other 80 percent is spent outside of school during the weekends, summer, and in supervised afterschool programs (NRC, 2009). Beyond school hours, the outdoors offers great opportunities to learn about science, and about environmental science in particular. Children can develop their understanding of evaporation and water flow by exploring puddles and drains, they can investigate animal behaviors by observing birds and bugs, and they can learn about life cycles by watching plants sprout, grow, flower, and create seeds. Such experiences can particularly benefit young children when they do these activities with their parents, since informal family science experiences in early childhood have been found to contribute to a greater understanding of science later in life (Tao, Oliver, & Venville, 2012). Given this potential, IE programs are well-positioned to fill gaps in experiences that put many students at a disadvantage in school and beyond.

However, informal education programs are tasked with a lot; they are expected to offer fun and entertaining programming, and are under increasing pressure to include academics, especially STEM, as well as physical fitness in their programming (Hynes & Sanders, 2010; Wiecha, Hall, Gannett, & Roth, 2012). While an IE organization may specialize or thrive in

achieving one of these priorities, efforts to achieve multiple priorities can be difficult. Incorporating outdoor exploration can add another layer of challenge, especially for programs located in urban settings that often do not recognize or feel prepared to take advantage of opportunities to explore environmental science in city neighborhoods. For this reason, the opportunities afforded by the outdoors in urban environments often go untapped.

PLUM Rx **Initiative**

Media producers at WGBH and researchers at EDC partnered to launch *PLUM Rx: Researching a new pathway for bringing active science exploration to urban families.* The goal of the project is to leverage the potential of IE programs to take advantage of the rich and varied opportunities for outdoor science learning for children ages 6 to 9 in urban settings. Funded by the National Science Foundation (NSF Grant #1516466), *PLUM Rx* builds on PLUM LANDING, an NSF-funded, PBS KIDS project that uses animations, games, and hands-on activities to motivate children to investigate the natural world. In the course of this 3-year initiative, WGBH and EDC have (1) developed a better understanding of the needs and opportunities for outdoor, active environmental science exploration among IE programs that serve urban children and families; (2) developed the *PLUM LANDING Explore Outdoors Toolkit,* a set of resources that expands PLUM LANDING's rich array of media assets in order to support informal educators and urban families when engaging in environmental science activities, and; (3) built knowledge and informed the field about the circumstances, educator practices, and resources that support the effective integration of science activities and digital media to spark and sustain urban families' exploration of core environmental science concepts in natural environments.

We began these efforts by partnering with outdoor prescription programs (Rx programs). These programs are part of a movement in which healthcare providers write children "prescriptions" for outdoor activity and informal educators "fill" these prescriptions by facilitating their participation in outdoor activities (Jaffe, 2010; Hamblin, 2015). They represent a promising approach for engaging urban children and families in active outdoor activities. Rx programs build on research suggesting that outdoor exploration can promote positive attitudes and healthy behaviors (Jaffe, 2015; Hamblin, 2015; Center for Disease Control [CDC], 2014), which are particularly critical in urban areas and in low-income communities where children are disproportionately affected by health issues such as obesity, asthma, attention disorders, self-regulation issues, low self-esteem, anxiety, depression, and stress. In developing our project, we recognized a missed opportunity in many of these programs to promote environmental science learning alongside outdoor exploration, and that integrating a science learning component into Rx programming would be particularly valuable for children in low-income urban communities given that they typically have less access to high-quality science learning opportunities.

Although infusing science into outdoor Rx programming was a driving force behind our research and development work, we aimed to ensure that the *Toolkit* resources would appeal to and address the needs of a broad range of informal programs serving urban children and families. We had reason to believe that resources designed to help infuse active, outdoor science learning into Rx programs could bring benefits to a wider range of programs, since Rx and IE programs typically share certain key premises in that 1) they are free-choice learning experiences without curricular or participation requirements; 2) they are facilitated by informal educators with varying degrees of resources, support, experience, confidence, and expertise relating to science and working with youth and families; and 3) they aim to serve children living in urban, low-

income communities where resources and additional support are often needed to connect to natural environments. Findings from our research confirmed our expectation that Rx and IE programs indeed share these characteristics, which allows the resources we developed to align to the needs and assets of both types of programs.

The *PLUM Rx* project team developed the *PLUM LANDING Explore Outdoors Toolkit* through multiple phases of work involving: a needs assessment to guide resource development by identifying local assets and obstacles that influence the extent to which, and ways in which, urban children and families engage with science in outdoor and informal contexts; a formative resource review of early resource prototypes for the development of a *Toolkit* consisting of digital media resources (animations, videos, and games), hands-on activities, and support materials for informal educators, informal program directors, and parents; a pilot study in which three Rx programs implemented draft *Toolkit* materials to inform additional *Toolkit* development and refinement; an implementation study in which *Toolkit* resources were implemented in 10 informal programs, including Rx programs and other IE programs; a scale-up review with a broad range of IE organizations in order to ensure widespread appeal, and; finalization and national dissemination of the *PLUM LANDING Explore Outdoors Toolkit* and research findings.

This report looks across these phases of work to discuss the *PLUM Rx* project's contributions to broader knowledge about supporting children's active, outdoor science exploration in informal, urban settings. In the following sections, we (1) describe the rationale for the design principles that guided the development of the *Toolkit,* integrating findings from prior research and literature, as well as findings from early phases of the *PLUM Rx* project; (2) briefly outline the *Toolkit* components that were developed in accordance with the design principles; and (3) summarize key findings about the various ways in which the integration of the design principles served to support urban children's engagement in informal, active, outdoor environmental science learning. Throughout, we draw heavily on data collected via researcher observations and through interviews and surveys of parents and informal educators who participated in the *PLUM Rx* implementation study.

Design Principles Guiding Our Work

Although there are many assets in low-income, urban communities that can be leveraged for robust environmental science exploration, there are also a multitude of factors that can make it difficult for IE programs to engage children and families from these communities in meaningful, informal outdoor science learning opportunities. The *PLUM Rx* project team set out to build on what was known and generate new knowledge about stakeholders' assets and needs, as well as the barriers that prevent them from engaging children and families in outdoor science activities.

In this section, we introduce and describe a set of design principles that guided our work, drawing both on findings from prior research as well as findings from early phases of the *PLUM Rx* initiative. These design principles reflect our efforts to support IE organizations, educators, and parents in promoting outdoor science engagement and learning among urban youth and families by leveraging their assets while also addressing constraints that we learned often make engagement in outdoor science activities difficult. The design principles fall into six categories: 1) increasing **access** to science learning opportunities, 2) **preparing** educators and parents for science activities and supporting implementation, 3) optimizing **time and space** available for outdoor informal science activities, 4) fostering the achieivement of multiple organizational

and/or familial **priorities**, 5) ensuring **safety**, and 6) using **technology and media** in meaningful and developmentally appropriate ways.

1. Increasing Access

For parents and educators to engage their children in meaningful science exploration, they need access to science resources that are aligned with what is known from past research about how to support high-quality science learning. However, resources like this that also meet the unique needs of urban children and families are in short supply. To address this need, we built on prior knowledge about the design of high-quality instructional materials in the development of the *PLUM LANDING Explore Outdoors Toolkit* resources. We knew, for example, that topics and concepts must be developmentally appropriate, focus on big ideas rather than discrete facts, and engage children in science practices and discourse as means to build conceptual understandings (NGSS Lead States, 2013; Duschl et al., 2007; French, 2004; Gelman & Brenneman, 2004; Yoon & Onchwari, 2006; Benjamin, Haden, & Wilkerson, 2010; Callanan & Jipson, 2001). We also knew that ideal science concepts and practices are those that can be examined or used across multiple contexts to explain important aspects of the natural world (National Research Council, 2012). Additionally, topics and big ideas are best when they relate to experiences children have in their daily lives, are accessible to children's direct exploration, are about things and events that children can explore deeply and over time, and are engaging, challenging, and fun (Chalufour & Worth, 2006). We also drew on past research that hands-on explorations are at the heart of inquiry (Chalufour & Worth, 2006) and should be at the center of efforts to engage children in science. With all of this in mind, a design principle that guided *PLUM Rx* was *to develop science resources that promote urban children's learning of important, relevant science concepts and practices across contexts through their engagement in local, hands-on nature-based experiences*.

Even when appropriate high-quality resources are available, urban, low-income families may have trouble accessing science programming. Nationwide, low-income parents face more challenges than those with higher incomes when it comes to finding affordable, high-quality afterschool activities and programs (Pew Research Center, 2015)**.** During our needs assessment, IE program directors and educators confirmed that the families they serve have difficulty locating quality science opportunities for children. Specifically, they explained that science resources and facilitated science programs are often out of reach for low-income urban families because they are costly, far from home, not accessible via public transportation, or rely on fluency in English. In addition, informal programs and their educators who aim to serve these communities lack access to high-tech tools that are typically associated with science investigations (e.g., telescopes). Moreover, exploring the outdoors on their own was also difficult for families because they lacked ideas and structure for what to do in the outdoors.

For these reasons, an important design principle that guided *Toolkit* development was *to develop resources that are free, make use of common materials, are available in Spanish and English, and provide ideas and support for children and families to engage in outdoor science activities near their homes and in a range of easily accessible urban settings*.

2. Preparing Parents and Educators

The adults in children's lives can play critical roles in supporting children's outdoor science learning. However, research shows that parents and educators often feel unprepared to lead science activities; they lack confidence because they feel they do not have the background

information, experience, or knowledge about how to do science activities in ways that support children's learning (Silander, Grindal, Hupert, Garcia, Anderson, Vahey, & Pasnik, 2018). These concerns can result in lost opportunities for families. During our needs assessment and pilot study, it became clear that parents need guidance to help their children make sense of science concepts promoted in the activities, to meaningfully engage in science practices such as asking questions and interpreting new information, and to inspire their children to reflect and build on science experiences. Similarly, in IE organizations that have not previously offered science programs or in which science programming has not been a priority, educators often have limited if any science training or experience facilitating science activities, so they feel unprepared to do so. The IE programs we worked with said the background and experience levels of their educators varied greatly, and program directors had limited capacity to prepare them for the demanding job of leading outdoor, physically active science activities with children and families. Moreover, IE organizations often have limited resources to dedicate toward training. A design principle in our work, therefore, was *to provide parents and educators who may have varying degrees of prior knowledge and experience with information, structure, and other supports so that they are prepared to promote children's science engagement and learning.*

3. Optimizing Time and Space

Perceptions about the time and space needed for outdoor science activities also hinder the extent to which parents and IE programs feel they can engage children in active, outdoor nature exploration. Through our research, we learned that parents feel they lack the time to do outdoor science activities with their children, and informal educators see the shortage of time they have to prepare for and implement activities as an impedient. This is consistent with national survey findings in which parents reported that they are prevented from enjoying more hands-on science activities with their children because they do not have enough time (Bayer Corporation, 2015). Additionally, the presence of nature may not be obvious in urban spaces that lack open green space, so children as well as parents and educators do not take full advantage of neighborhood assets that can provide fertile ground for science exploration. A design principle, therefore, was *to create activities that inspire and enable parents and educators to do science with their children in the time and local urban spaces they have available.*

4. Achieving Multiple Priorities

Parents and IE organizations have particular priorities for how they want to invest time and resources. In our research, we found that many families prioritize activities that afford positive social, fun, interactive experiences more than activities that emphasize physical fitness, being outdoors, or learning. Similarly, IE programs and their educators vary in their missions; some prioritize academics (e.g., math, literacy, science), outdoor activity, athletics, or fun, but few attempt to address multiple priorities in a single program. Additionally, IE programs vary in how they deliver programming; some serve only children while others serve families, some cater to children in a particular age range while others invite children of all ages, and some schedule events while others provide resources for children or families to use on their own (Roth, 2016). Given differences such as these, a design principle for our work was *to develop a Toolkit of resources that enable parents and IE organizations to engage children in activities that help them achieve multiple priorities, and that can be implemented in accordance with a range of program delivery models.*

5. Helping to Ensure Safety

Concerns about safety in urban settings often limit children's engagement with outdoor science. We found safety to be a major concern among families in our research, which is consistent with research that shows that, across the country, low-income parents are more likely to worry about their child's safety than high-income parents (Pew Research Center, 2015). During our needs assessment, we learned it is common for families to associate inner city parks with criminal activity (e.g., muggings, rapes, drug use). Families also have nature-based safety concerns, such as poison ivy and bugs, that make them hesitant to engage in outdoor science activities. Concerns about safety are not limited to parents; we heard from one IE program director that many children do not feel safe outside, and that fears are particularly acute among immigrant families coming from cities where parks and open spaces were common settings for violence (related to war, drug activity, and other crime). Perhaps as a result of these types of safety concerns, our parent survey data suggest that many children who live in walking distance to public parks and sports fields are not spending time in those outdoor spaces and, therefore, are not taking advantage of the learning opportunities they afford. Our needs assessment also revealed that safety concerns pose challenges for many urban IE organizations that provide programming. For example, educators we spoke with reported that science activities in which children sit on the ground or search brushy areas in urban parks to find particular plants or insects may not be appropriate because of the possible presence of drug paraphernalia. To address concerns about safety, a design principle was *to develop resources that acknowledge the validity of safety concerns while also offering tips and clear instructions for how to plan for activities and maximize safety when conducting outdoor activities in urban settings.*

6. Using Technology Wisely

Finally, concerns about the use of technology and media result in missed opportunities for urban youth and their families. Our research found that parents are often concerned about the amount of time their children spend using technology and media, and are particularly wary about using technology during family time or while outdoors. Even when families do want to use technology, limited access to technology and/or limited data plans constrain the ability of many families to use digital resources outdoors or at home. Moreover, educators often do not have access to, do not want to, or find it difficult to use technology and media during facilitated activities. Even though afterschool programs had more access to technology and were more open to using it, we found that outdoor education organizations rarely make use of technology during activities; as we learned in our early formative research, there are few, if any, technology devices allocated for on-site programming, and program staff often perceive technology and media use as in conflict with their organizational missions.

More than four decades of research on children's learning with educational technology and media highlight the positive role that judicious use of technology can play to support learning (Bogatz & Ball, 1971; Fisch, 2004; Fisch & Truglio, 2001; Pasnik & Llorente, 2013; Thakkar, Garrison, & Christakis, 2006), and offer useful implications for the effective integration of technology into science instruction. For example, digital activities have the potential to support and build on hands-on investigations by providing novel ways to engage children in science learning, including activities that are not feasible in the classroom and that enable children to practice what they learned in the physical environment. Integrating technology and media into programming has also been found to provide a means to attract and engage children in outdoor science activities (Chavez, 2009). In developing the *PLUM LANDING Explore*

Outdoors Toolkit, a design principle was *to leverage the affordances of technology and media in developmentally appropriate ways to inspire children's engagement with fun, social, and physically active outdoor science experiences.* Additionally, we set out *to use technology and media as a means to provide additional support for parents and educators through the provision of tips, preparatory information, and digital supports.*

Design Principles

1. To increase access, develop science resources that promote urban children's learning of important, relevant science concepts and practices across contexts through their engagement in local, hands-on nature-based experiences
2. To increase access, develop resources that are free, make use of common materials, are available in Spanish and English, and provide ideas and support for children and families to engage in outdoor science activities near their homes and in a range of easily accessible urban settings.
3. To prepare parents and educators, provide parents and educators who may have varying degrees of prior knowledge and experience with information, structure, and other supports so that they are prepared to promote children's science engagement and learning
4. To optimize time and space, create activities that inspire and enable parents and educators to do science with their children in the time and local urban spaces they have available.
5. To achieve multiple priorities, develop a Toolkit of resources that enable parents and IE organizations to engage children in activities that help them achieve multiple priorities, and that can be implemented in accordance with a range of program delivery models.
6. To help ensure safety, develop resources that acknowledge the validity of safety concerns while also offering tips and clear instructions for how to plan for activities and maximize safety when conducting outdoor activities in urban settings.
7. To use technology wisely, leverage the affordances of technology and media in developmentally appropriate ways to inspire children's engagement with fun, social, and physically active outdoor science experiences
8. To use technology wisely, use technology and media as a means to provide additional support for parents and educators through the provision of tips, preparatory information, and digital supports.

Toolkit **Description**

Once the *PLUM Rx* team had a well-developed set of design principles in place, we used them to inform the creation of the *PLUM LANDING Explore Outdoors Toolkit*. The *Toolkit* includes a set of resources designed for three different implementation models commonly used by IE organizations that provide programming beyond school hours:

- Afterschool model: Children attend weekday afterschool sessions in which at least one educator leads them through hands-on, outdoor science activities.
- Family-facilitated model: Families attend sessions in which at least one educator leads them through hands-on, outdoor science activities. Children and all family members in attendance are encouraged to participate. These sessions may be conducted on a weekend

day (as they typically were during the implementation study), or at another time when families can attend.

- Family self-guided model: Parents are provided hands-on, outdoor science activities and asked to implement them with their children on their own, at a time and place that are convenient for them.

The *Toolkit* includes resources for each model, as shown in the table below. Hands-on activities were created for all three models, and were designed to support active outdoor science exploration in urban neighborhoods. Hands-on activities for the afterschool and family-facilitated models include background information for educators and three core activity components: warm-up, main activity, and wrap-up. Additional components include a suggested video for introducing the topic, and ideas for children or families to further explore the activity's focal topic (referred to as *Explore Some More* activities). Hands-on activities for the family self-guided model include a short introduction for parents, a main activity, and *Explore Some More* activity suggestions.

Supplemental resources intended to be used across models include: animated videos designed to get children excited and introduce science content; take-home activities offering suggestions for follow-up outdoor science activities, additional media resources, and books that families can explore at home; educator videos that provide educators with strategies for leading active, outdoor science activities; parent videos that provide families with tips and inspiration for getting the most out of their time outdoors together; and an app to provide families with ideas and encouragement for sustained outdoor exploration. All materials for parents were produced in both English and Spanish.

Table 1: PLUM LANDING Explore Outdoors Toolkit Components

Activity Component		Implementation Model		
		Facilitated Afterschool (child only)	**Family Facilitated**	**Family Self-Guided**
Hands-on	Warm-Up Activity	•	•	
	Main Activity	•	•	•
	Wrap-Up Activity	•	•	
	Introductory Video	•	•	
	Explore Some More	•	•	•
Supplemental	Educator Videos	•	•	
	Take Home Activities	•	•	
	Caregiver Videos	•	•	•
	Animated Videos	•	•	•
	Outdoor Family Fun with PLUM app			•

Knowledge Generated

Once the *Toolkit* was created, piloted, and revised, the *PLUM Rx* team conducted an implementation study in which ten informal education organizations across the country implemented the *PLUM LANDING Explore Outdoors Toolkit* in their programming. Overall,

findings from the study showed that the *Toolkit* promoted urban youth and families' participation and engagement with target science concepts and practices across a range of informal, outdoor contexts (see Goldstein, Famularo, Pierson, Kynn, Bates, & Durham, 2018), with some variation in the usefulness of particular *Toolkit* components by implementation model. Along with the design principles described above, and the *Toolkit* itself, we consider the broader impact of this work to be the knowledge generated about how the circumstances, educator practices, and resources common to informal education programs can support the effective integration of science activities and digital media to spark and sustain urban families' exploration of core environmental science concepts in natural environments.

In this section, we describe what we learned about our design principles in leveraging assets in urban communities to address needs and overcome barriers to provide children and families in urban communities with meaningful, outdoor science learning opportunities. The findings are organized by the six design principle categories described above.

1. Knowledge about Increasing Access

Facilitated activities designed to take place in locations easily accessible to urban families can successfully attract and retain children and families, and engage children in hands-on, nature-based experiences. For parents in urban settings, science programs are often out of reach because they are offered at locations that are far from home or inaccessible via public transportation. In our studies, facilitated activities took place in locations easily accessible to families. For example, activities took place on school grounds, at an urban beach located across the street from a subway station, and a public park that was walking distance from a bus stop. We witnessed high attendance rates and evidence of science teaching and learning, serving as a proof of concept that it is feasible to design educational, nature-based activities that take place in residential urban communities.

Resources designed to focus on *Big Science Ideas* (rather than discrete facts) and engage children in science practices and discourse can promote children's learning of relevant science concepts and practices. The *PLUM LANDING Explore Outdoors Toolkit* resources were designed to support the teaching and learning of science concepts centered around the B*ig Science Ideas* that were specified as learning goals for each activity. They related to weather, water, animals, and plants that exist in, or otherwise impact, urban environments**.** The activity sheets included discussion questions designed to engage children in science discourse related the *Big Science Idea*. Findings from the implementation study indicated that *Toolkit* resources were both developmentally appropriate for children ages 6–9 and supported educators and parents in using a variety of strategies to introduce and promote children's learning of important science concepts in city neighborhoods. According to parents, their children learned about the weather, clouds, "moving water," different types of leaves, that "leaves sweat," "shadows and position of the sun," how bees communicate to find food, how seeds travel, to "identify animals and their tracks," and how animals make and find shelter to protect them from predators. Children also demonstrated that they could relate what they learned about the *Big Science Ideas* to their everyday lives and immediate surroundings, suggesting they were able to transfer new knowledge to other contexts. The resources also supported children's learning of foundational science skills by engaging them in science practices. These included structured, multi-step scientific processes (such as conducting experiments, making predictions, observing and

comparing results, and engaging in repeated cycles of predicting, experimenting, and observing), as well as individual science practices such as asking questions, making predictions, conducting close observations, making comparisons, and interpreting data.

Activities that made use of common, low-cost or free, easy-to-use and easy-to-transport materials can enable educators and caregivers to engage children in outdoor science investigations. We learned that science is not currently a focus of many IE organizations and, as a result, informal educators often lack access to resources typically associated with science investigations (e.g., microscopes, balance scales). To address this, *Toolkit* activities were designed to utilize materials that are common, low- or no-cost, easy to use, light enough to carry to the outdoor sites, and that many IE organizations and families already have (e.g., water bottles, yarn, jump ropes). Educators and caregivers appreciated these features of *Toolkit* materials, and they helped ensure that activities' cost and preparation requirements did not make them out of reach for organizations, educators, or families.

Multiple strategies are needed to increase access for parents whose primary language is not English. To increase access for immigrant families with limited English proficiency, the *Toolkit* offered parent-facing resources in Spanish as well as English, and some of the participating IE organizations used bilingual educators to facilitate family programs. Although translated materials helped engage some Spanish-speaking parents, we found that some parents had limited literacy in any language, and were not able to use translated handouts. These parents were only able to gain access to the *Toolkit* resources through participation in activities facilitated by Spanish-speaking educators. Given that the U.S., and many urban centers in particular, is home to immigrant families who speak a variety of languages, an acknowledged challenge is to create resources that are accessible for parents who speak a language other than Spanish and English. Resources for home use should also be accessible to parents with limited levels of literacy.

Materials designed to reflect the racial and ethnic diversity and cultural perspectives of the communities resonated with the educators and families and made the materials relatable. In addition to increasing access to environmental science learning opportunities, the resources were developed with the goal of being relatable to families in urban communities. In the *Toolkit's* live-action videos, the narrators were Rue Mapp of Outdoor Afro, and José González and Melissa Avery of Latino Outdoors. These narrators were relatable and passionate speakers (which made them appealing to educators and parents), and their respective African American and Latino heritage mirrors the ethnic and racial makeup of many urban communities. The children and caregivers featured in videos and animations also represented a level of ethnic and racial diversity that is common among urban communities. During our scale-up review of the *Toolkit* with IE organizations, reviewers called out the narrators' diversity and relatability as key strengths of these videos and suggested that these features would make the resources resonate with the educators and families they serve.

Providing an array of materials for at-home use among families participating in self-guided programs can encourage caregivers to engage their children in science activities at home. As noted earlier, parents need ideas and support for structuring meaningful outdoor science experiences for their children. To address this need, the *PLUM LANDING Explore Outdoors Toolkit* included several resources designed to support parents in their efforts to engage children

in outdoor science activities. Self-guided, hands-on activities for families enabled parents to facilitate outdoor science exploration with their children at a time and place of their choosing. The *Toolkit* included a series of videos offering families tips and inspiration for exploring nature in their neighborhoods. For example, they suggest moving leisure activities typically done indoors to the outdoors, and incorporating nature exploration into everyday outdoor activities. The *Toolkit* also included a series of digital resources for children and families designed to supplement learning on the topics explored during hands-on activities. Animated videos provide an introduction to outdoor exploration and reinforce science topics. An app, entitled *Outdoor Family Fun with Plum*, provided additional ideas, structure, and inspiration for families to engage in nature-based explorations. Embedded missions in the app offered a variety of science activities for families to do outside, such as counting clouds or taking photos of plants growing in unusual places, and make use of various easy-to-learn mechanics (including a timer, camera, or counter). For a subset of participating parents who implemented self-guided resources, the app was more successful than the printed activity sheets in promoting participation in outdoor science activities. As a result of these multiple methods for supporting at-home science teaching and learning, the self-guided resources were shown to enable parents, with varying degrees of knowledge and experience, to promote science, physical activity, and fun.

More research is needed to understand how to best encourage families participating in facilitated programs to continue exploring on their own. The *PLUM Rx* team created *Toolkit* resources to support home-based learning among families who participated in educator-facilitated activities. Unfortunately, educators did not distribute these "take-home activities" as intended and, as a result, many parents did not know about them and could not use them. To build on the limited knowledge generated about the value of the take-home activities and the characteristics of effective resources of this kind, valuable future research would seek to identify the best approaches for informing parents about these sorts of extension activities and supporting their more widespread implementation, thereby improving families' overall access to these types of learning opportunities.

2. Knowledge about Preparing Parents and Educators

Parents and educators with limited science knowledge and experience can benefit from well-designed hands-on activities that make learning goals explicit and include structured, step-by-step instructions that are easy to follow. Adults, who are in a position to support children's science learning, often need guidance for engaging children in experiences that will develop their science knowledge and skills. Activities developed for educators and used during the implementation study provided a sentence describing the *Big Science Idea* and a bulleted list of the science skills that children were expected to engage in during each activity. In the same call-out box, a bulleted list of steps described "how to get ready" for the activity, including preparing materials, finding an ideal location, and troubleshooting potential safety concerns. On the right side of the page, in bold, were listed the Curriculum Topics, Activity Type, Group Size, Activity Time, and Materials. This clearly defined and outlined information served to orient educators toward promoting the activity's central science concepts and helped set expectations and prepare them for what they were going to implement. Activities also provided numbered, step-by-step instructions embedded with scripted prompts to help educators introduce activities and solicit ideas and discussion from participants. Those developed for parents included a brief introduction to the *Big Science Idea* and similar step-by-step suggested procedures.

Both educators and parents appreciated this general layout and flow of the printed activity sheets. Feedback from educators and parents suggested they would welcome the incorporation of additional supports into activity sheets as well, such as more embedded background information about the science concepts, more reflection questions to help children connect concepts with real-world situations, and guidance for choosing and adapting activities for different ages, abilities, group dynamics, weather conditions, or regional variations (e.g., local flora and fauna). Following the implementation study, many of these suggestions were incorporated into the redesigned *Toolkit* resources.

Educators and parents, who feel unprepared or lack confidence in facilitating science learning, appreciate activities that include games, which can make the science content more approachable while still promoting children's science engagement. Many of the *PLUM LANDING Explore Outdoors Toolkit* activities were designed such that science was integrated into the activities in a natural and game-like way. For example, the learning goal for one activity was to teach children about the different ways in which animals move through their habitats (e.g., flying, jumping, hopping, running, slithering, waddling) as they look for food, avoid predators, and interact. The activity involved a game in which children compete to see how well their physical skills stack up against some of the animals in their neighborhood. They learned first-hand that no child could jump 20 times their body length the way a grasshopper can, nor could any child run 45 miles per hour like a coyote. The goal of another activity was to examine how rainwater interacts with various city surfaces. It involved a "Red Rover"-inspired game in which children acted as raindrops and tried to get through a line of adults holding hands to model the behaviors of an impermeable surface (e.g., pavement) and dropping their hands to model a permeable surface (e.g., grass). Our research revealed that this game-like approach to activities made the science aspects of activities approachable, and helped educators and parents feel prepared to facilitate those activities even if they lacked specialized science knowledge or experience.

Digital resources can provide additional information and guidance needed to prepare and set the stage for educators and parents to lead outdoor science activities. Although the *PLUM Rx* team found that much of the support needed to implement hands-on activities with children and families could be integrated into the activities themselves, we also saw and fulfilled a need for additional resources that provide tips and strategies for engaging urban children and families in outdoor science programming. For example, as part of the *Toolkit*, we created a series of video-based tips for educators that include preparatory information, suggestions for guiding children and families through outdoor science activities, tips for addressing common challenges, and effective approaches for implementing science activities in outdoor and urban settings. These were valued by educators, particularly those who were new to outdoor IE programs. A similar set of videos created for parents touch on topics like how to find nature in city neighborhoods, easy ways to start exploring the outdoors, and how to support outdoor science exploration. The *Toolkit* also includes a set of short introductory animations intended for use at the beginning or end of the hands-on activities, in order to introduce or reinforce science concepts and get children interested in the focal topic without requiring background research or extensive preparation, or sacrificing physical activity or fun. Few participating caregivers used the video resources, so we are unable to report conclusions regarding their usefulness and effectiveness.

3. Knowledge about Optimizing Time and Space

Activities designed to utilize common features of urban neighborhoods that can be conducted with little preparation and in a short period of time can enable parents to effectively use areas within walking distance to their home as settings for outdoor science exploration. The *Toolkit's* self-guided activities and take-home resources were designed to make use of families' neighborhood assets. During our research, families made effective use of sidewalks, local playgrounds, small urban parks, and other settings within walking distance to their homes and utilized common features of these urban environments to explore topics relating to water, wind, animals, plants, and other important science topics. *Toolkit* activities were also successful in showing parents that they can incorporate science into their normal routine (e.g., while walking to and from school) by using strategies such as observing, counting, and cataloging. Feedback from some parents suggested that, as a result of their experience with *PLUM Rx*, they now see science and nature as things they can promote spontaneously in their neighborhood, without much preparation. For example, one parent articulated the realization that "All you had to do was go outside and look around." Similarly, another said that she had never thought about using the outdoors "as a teaching tool for math and science." Parents who we interviewed said that, as a result of their *PLUM Rx* experience, they have more ideas about what to do outdoors and that their families now spend time exploring, observing, talking about, and appreciating nature and natural phenomena. These findings suggest that *Toolkit* resources provided ways for families to leverage urban neighborhood assets to support children's outdoor engagement with science.

Activities designed to be modular and flexible can make the promotion of science more feasible for integration and use by informal educators who vary in the time and space they have available. Like parents, informal educators have limited time to prepare for and implement science activities, particularly when science is one of many organizational goals. Components of *Toolkit* activities that are related in content and approach were designed to be sequenced together to provide a meaningful and cohesive experience. Each component can also stand alone. This flexible design enabled educators to choose components of activities based on the time they had, as well as shorten or extend activities as needed. It also allowed them to choose activity components best suited for the space they had available (as mentioned previously, activities made use of locations commonly found in residential urban neighborhoods). Organization directors and informal educators stressed the benefit of having a range of short activity options to pull out "on the fly" if there is extra time during a facilitated session or if a pre-selected activity is not going well.

Environmental science activities that focus on *Big Science Ideas* about weather, water, plants, and animals supported learning across regions can be conducted in almost any setting, yet there is also a demand for activities tailored for individual local environments. Activities produced for the *Toolkit* focused on common elements such as clouds, wind, or grass, for example, so that they are not dependent on particular environmental features such as a pond, specific type of forest, or particular weather conditions. However, the *Toolkit* materials did encourage educators to make connections to special features of their local ecosystems via "plant and animal fact cards" that highlight common urban flora and fauna in different regions of the

US, and via training videos that encouraged educators to highlight local features. Despite this, educators who utilized the *Toolkit* expressed the desire for activities and resources that can be further curated or tailored for their local environments. This presents a design challenge for developers, given the great variations in flora, fauna, and environmental conditions across the United Stations.

4. Knowledge about Achieving Multiple Priorities

Incorporating *physical activity* into outdoor science activities can make outdoor science activities more appealing to children and families. Physical activity often takes a back seat to other priorities for both IE organizations and parents. However, as previously described, incorporating physical activity is crucial part of the *Toolkit* and an inspiration for its development. Our study showed that incorporating physical activity into activities is an effective pathway to engage children and families in science exploration. Thoughtful, physically active games and activities like mimicking animal movements, racing to complete scavenger hunts, and competing in predator/prey races engaged youth and their parents, while still achieving instructional goals. Throughout our implementation research, physical activity often was a key driver of children's engagement during activities, with children typically most engaged when they were participating in activities that included rigorous physical challenges. Moreover, in light of high rates of childhood obesity in many low-income urban communities, the *Toolkit's* promotion of physical movement bodes well for the broad and meaningful impact it can have in urban areas nationwide.

Incorporating opportunities for *fun and social interaction* can make outdoor science activities more appealing to children and families and can promote families' long-term participation and attendance. Families often seek out and favor activities that afford fun and social experiences over activities that foreground learning. We learned throughout our research that resources can support active outdoor science learning and still be fun and social. *Toolkit* activities enabled family members to interact with each other and meet new people through their playful rather than didactic approach to engaging with science. For example, warm-up activities often asked families to play together as a whole group, and wrap-up activities encouraged families to share the results of their investigations with each other. The high attendance rate at activities, positive educator feedback, as well parents' favorable attitudes toward continuing their involvement in outdoor activities suggest that social and collaborative activities are a means by which programs can promote families' long-term participation and attendance.

Facilitated family activities that provide a clear role for parents can be successful in engaging the entire family in outdoor science exploration. During our needs assessment, we learned that is not enough to design family activities that only children will enjoy; activities must be engaging and fun for parents, too, because ultimately parents decide whether to enroll and continue to attend family programs. We know that parents prioritize activities that afford positive social, fun, interactive experiences, so it is important to design programs that accomplish these goals and engage both children and parents. In the early stages of our research, we found that some parents attending outdoor science activities with their children did not actively participate; instead, they spent the time attending to other siblings, talking with other adults, or being uncertain about their expected role in the activity. We found that providing prompts for

educators to explicitly invite parents to participate and that provide suggestions for how to include their younger or older children were successful in engaging the entire family.

Incorporating opportunities for fun, physical activity, and social interaction into outdoor science activity does not need to come at the expense of science learning. Implementation of the *PLUM LANDING Explore Outdoors Toolkit* across a range of IE organizations illustrated that it is possible for IE organizations to facilitate the types of family activities that parents prioritize, that is, those that are fun and promote social interaction, and also accomplish the goals of science learning. As described previously, our implementation study suggests that children who participated in *Toolkit* activities learned important science concepts and made use of a range of science practices. For example, we observed children searching for answers to testable questions, documenting observations, and interpreting and sharing results. These forms of engaging with science in the context of active, fun, and social experiences are critical given the shortage of opportunities many children have to learn science in school and beyond.

Resources designed to address multiple priorities can be successfully implemented across IE organizations with a variety of missions. IE organizations vary in their missions and prioritize programs with particular characteristics that align with their core goals. *Toolkit* activities were designed to take place outdoors, promote fun, physical fitness, and learning, and incorporate technology and media resources. The *Toolkit* enabled participating IE organizations to fulfill their central missions, expand their institutional capacity by advancing additional goals, and appeal to a wider range of participants. For example, one partner outdoor prescription program in the Northeast United States has a central mission that "encourages children and their families to get more physically active outdoors." Science education is not explicitly part of their mission, but because *Toolkit* activities take place outdoors and are infused with highly active games and physical movement, they were able to easily integrate the *Toolkit* into already established programming and thereby add an additional layer of benefits for participants. In addition to providing ready-to-use resources to help IE programming achieve multiple priorities, there is the potential for the *Toolkit* to have broad impact as a model that IE organizations nationwide can use to develop their own activities to address both parents' desire for fun, social activities, and the need to promote science learning and physical fitness in outdoor settings.

There is value in developing resources that can accommodate a range of program delivery models. To effectively support their mission, IE organizations embrace particular program delivery models, such as programs that serve only children or programs that serve whole families. Through the *PLUM Rx* initiative, we designed environmental science resources that address multiple priorities (described above) for implementation in three program delivery models: educator-facilitated activities for children only, educator-facilitated activities for families, and activities for families to do on their own (i.e., self-guided). Participating IE organizations were able to successfully implement the *Toolkit* resources that most closely aligned with their existing program delivery model. There was evidence across all program delivery models that the resources promoted science teaching and learning. Additionally, some resources inspired organizations to offer new kinds of programming. For example, one organization that had previously offered only activities for children made use of the family-facilitated activities as a new way to engage families in outdoor exploration.

5. Knowledge about Ensuring Safety

Materials that address fears about safety were appreciated by participating program directors and educators, but more research is needed to understand their impact on families. As explained previously, the participation of urban families in outdoor science exploration is often constrained by their concerns about safety due to crime, drugs, and aspects of the natural environment that are unfamiliar or they find intimidating. *Toolkit* resources for educators addressed these constraints by integrating clear preparation instructions into activity sheets (including suggestions to survey the setting beforehand to ensure safety and to situate park-based activities within earshot of cars or foot traffic). Other support resources included text- and video-based tips that provide additional information about how to plan for activities and maximize safety when conducting outdoor activities in urban settings (for example, visiting parks on days when nice weather is likely to draw a crowd, and inviting other families to join in outdoor exploration). Feedback from educators who made use of these resources provided encouraging feedback regarding their appeal and perceived value. Educators and program directors rated the video-based tips highly and praised their sensitivity in dealing with a difficult topic. However, additional research is needed to identify the ways in which such resources may address families' concerns and foster positive, sustained changes in their attitudes and behaviors around doing science activities outside.

6. Knowledge about Using Technology Wisely

Multimedia resources that leverage the affordances of technology have potential to inspire and support outdoor science exploration. Educators and families were inconsistent in their use of digital resources during *Toolkit* implementation, but when they were used, evidence showed that the resources captured children's attention, provided opportunities for learning, and got them excited about being outdoors and in nature. Our research pointed to a number of examples of positive uses of technology to explore nature:

- Short videos can spark children's interest and prepare them for learning by introducing science concepts, stimulating discussion, and catalyzing physical activity. For example, during a *Toolkit* activity designed for children to understand that migrating animals depend on stopover sites (pockets of habitat that provide food, water, and shelter), educators began by playing a video. The video featured a U.S. Forest Service ranger who takes a group of children on a hike through the city to find places where animals might live. After showing the video, educators posed a series of questions about the video to prompt a short conversation about animals that live in their city, their habitats, and where and why they might migrate. This was a motivating segue into the more active part of the activity in which children looked for stopover sites in their own immediate surroundings.
- Digital resources such as videos, games, simulations, or other online resources related to activity topics can be used by parents before an activity to get their children interested in the topic, or after an activity to reinforce learning. The migration activity mentioned above, for example, suggests that families explore the topic further by accessing the Audubon's Guide to North American Birds, available at audubon.org/bird-guide, or by exploring interactive migration maps on the eBird.org website.
- Common features of digital devices (e.g., mobile phones, tablets), such as a stopwatch, compass, and camera, can support learning. For example, a mobile phone's camera or

video feature was used during activities to encourage children to search and closely observe their surroundings, as well as to document and review observations to develop their understandings about the natural world.

- Digital apps can be used to guide and document science investigations and promote joint media engagement and collaborative learning. For example, the *Outdoor Family Fun with PLUM* app includes various "missions" that prompted families to search for common features of urban environments (e.g., leaves, squirrels, pigeons), and record how many they find in order to earn digital rewards.
- Apps on mobile devices can provide a way for families to overcome concerns about time and space for outdoor exploration by integrating collaborative scientific play into their daily routine. For example, in our study, families used the *Outdoor Family Fun with PLUM* app to explore nature on their walk to and from school, and in the car on their way soccer practice.
- Videos can support educators by providing them with tips for how to prepare for outdoor science activities, as well as support educators in engaging children in outdoor science learning without having to be the sole communicators of science content. Our study found that these videos were particularly useful for educators with less experience.

Despite these benefits, some educators and parents may not be convinced of the value of technology in supporting nature-based exploration. Educator and parental attitudes towards the integration of technology was mixed; some educators saw technology use as a nonexistent or peripheral component of their program (and wished to keep it that way), and many parents expressed a wish to discourage or minimize their children's screen time. It would be valuable for future research to identify best approaches for achieving buy-in among educators and parents, and best practices for leveraging the potential of technology and media to support active, outdoor science learning.

Broader Contributions and Future Research

Throughout the three-year initiative, the *PLUM Rx* project team identified and generated new knowledge about how to develop resources to bring active, outdoor science learning to the underserved population of low-income urban families. This work required close examinations of the kinds of programming that Rx programs and other informal education organizations offer for children and families, the roles that educators and parents can play in supporting outdoor science learning in urban settings, the assets and obstacles that influence how key stakeholder groups engage with science in outdoor and informal contexts, and the characteristics of resources that successfully engage children and families in outdoor science learning.

Findings from our early stages of research, combined with prior research on informal science exploration, guided the development of a series of design principles, which in turn informed the development of the *PLUM LANDING Explore Outdoors Toolkit.* Iterative development and testing of the *Toolkit* components subsequently enabled us to learn more about how IE programs address assets and obstacles relating to access, preparedness, time and space, multiple priorities, safety, and technology. In addition to being a ready-to-use and much-needed set of resources for families and IE organizations nationwide, the *Toolkit* can serve as a model for for others who seek to bring active, outdoor science learning opportunities into the lives of urban children and their families.

The results of our work are encouraging and highly valuable to those invested in promoting active, outdoor science exploration among urban children and families—but there is more to learn. Future research would be wise to examine how to support families in extending the learning that happens in educator-facilitated activities, as well as how to communicate the value of digital tools for promoting science learning during facilitated sessions, at home, and in other informal contexts. The identification of ways to help educators and families adapt activities to local contexts also represent promising avenues for future research. Finally, valuable future research would involve a large-scale randomized controlled study to rigorously examine the *Toolkit's* impact on child learning.

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